2021

Outcomes and Complications of SCFE Surgery

Tyler Sanda

Outcomes and Complications of SCFE surgery

Tyler Sanda

Melissa Martinek, Dayton Childrens Hospital Department of Orthopaedic Surgery

Clinical Sciences

Scholarship in Medicine Final Report

☒ By checking this box, I indicate that my mentor has read and reviewed my draft proposal prior to submission

Abstract

Objective: Slipped capital femoral epiphysis (SCFE) is a common hip disorder affecting children and adolescents. There is much debate concerning best treatment with regards to adverse outcomes, specifically avascular necrosis (AVN). This study analyzed the rates of adverse outcomes after the surgical treatment of SCFEs. It examined risk factors which may lead to the development adverse outcomes. This research will aid clinical decision-making, helping determine optimal surgical treatment of SCFEs and adding to external datasets of SCFE treatment.

Methods: This was a retrospective review of patient health records at a level 2 pediatric trauma hospital. The study included all SCFE procedures performed at the hospital from 2005-2018. Data collected included age, gender, BMI, surgical fixation and complications. Descriptive statistics included frequency (percent) used for categorical variables and mean (range) for continuous variables.

Results: A total of 222 total cases were reviewed. In situ pinning (ISP) was performed in 203 cases, ISP with hip capsule decompression in 13, and the modified Dunn in 6. Avascular necrosis occurred in 3.4% of ISP cases, 7.7% of ISP with hip capsule decompression, and 66.7% of modified Dunn cases.

Key Words: Slipped capital femoral epiphysis, SCFE, in situ pinning, modified Dunn procedure, Avascular necrosis, complications

Introduction/Literature Review

Slipped capital femoral epiphysis (SCFE) is a disorder in which a skeletally immature hip is anatomically disrupted through posterior translation of the proximal femoral physis along with an anterior displacement of the metaphysis.[1,2,3] SCFE is one of the most common hip disorders affecting children and adolescents, typically occurring at the mean ages of 12 years in boys and 11.2 years in girls. There is often no source of trauma and it commonly presents as pain in the groin, thigh, hip, or knee. Although the exact mechanism by which a SCFE develops is unknown, it is believed to be a multifactorial disorder with a link to obesity, endocrine disorders, and renal failure, with the highest emphasis on obesity.[2] One study found that 45 of 53 SCFE patients were obese with higher hemoglobin A1C levels compared to a control group.[4] These results warranted the possible discussion about monitoring SCFE patients for future development of type 2 diabetes mellitis. In general, obese children often have an earlier onset of SCFE than non-obese children.[5]

Although there are multiple ways to classify a SCFE, one commonly used metric is the stability of the slip. A patient with a stable SCFE is weight bearing, while a patient with an unstable SCFE demonstrates no weight bearing ability, with or without crutches. SCFE can also be classified by the degree of displacement. Mild cases have less than 33% of the physeal diameter, moderate have between 33%-50%, and severe have greater than 50% of the physeal diameter displaced.[6–8] Finally, a SCFE can be classified into 3 categories based on the timeline of injury; acute, chronic, or acute on chronic. An acute SCFE is defined by onset of symptoms occurring for <3 weeks, a chronic SCFE has symptoms present for >3 weeks, and acute on chronic is defined as when symptoms occur abruptly with exacerbation of pain occurring for >3 weeks.[9]

The correct treatment course after the onset of SCFE is highly debated. Currently, treatment is largely determined by the stability of the slip. The most commonly practiced treatment of a stable SCFE is an in situ pinning (ISP), during which a screw is placed to fixate the bone perpendicular to the physis.[2,10–12] This should prevent additional displacement and decrease the risk of AVN and further deformity. Although it is believed that ISP has the lowest risk of avascular necrosis (AVN) there are some studies that demonstrate that the procedure may lead to long term sequelae of hip mobility and functionality; these complications include osteoarthritis and femoroacetabular impingement (FAI).[13,14] Unstable SCFEs are typically treated with either ISP or the new modified Dunn procedure, and there is much discussion regarding each procedures' adverse outcome rates, particularly of AVN. The new modified Dunn procedure consists of an open reduction and fixation of the SCFE,[6,15] but there is inconclusive evidence as to which surgical style minimizes AVN risk. The procedure is typically used in acute, unstable SCFE patients, which are inherently at a greater risk of complication.[7]

In our study, we analyzed the rates of post-operative AVN following ISP or the Modified Dunn procedure and compared these results to previously reported rates. We hypothesized that our rates of AVN after ISP, the dominant procedure performed at Dayton Children's Hospital, would be at the reported rates of similar healthcare facilities. We also examined potential risk factors that may correlate with the development of post-operative AVN. This research will aid clinical decision-making, helping determine optimal surgical treatment of SCFEs and adding to the external datasets of SCFE treatment.

Hypothesis/Specific Aims/Research Questions

In our study we hope to analyze the rates of AVN postoperatively at Dayton Childrens Hospital and compare them to other recently reported studies. Dayton Childrens hospital primarily uses the pinning method while performing SCFE surgeries. We will therefore compare AVN rates following pinning procedures with the other reported studies using the same procedure. This information may also be compared to the modified dunn procedure in hopes of identifying a superior procedural technique. This may help future surgical decisions and training for the

treatment of SCFE at DCH. We hope this will further the effort amongst the pediatric orthopedic community to solidify the methods chosen for SCFE surgery dependent on the type and severity of the slip.

Methods

We will be retrospectively reviewing both electronic and physical copy charts at Dayton Childrens hospital for the past 20 years. This will be a retrospective cohort study which will analyze outcomes following the pinning procedure used in the correction of a SCFE.. In this review we will analyze the rates of AVN in treated patients along with noting any other adverse outcomes for children. We will compare the outcomes using rate comparisons such as relative risk, confidence intervals and two sample t-tests. The total amount of patients used will range from 250-400 depending on defined inclusion/exclusion criteria Other variables such as obesity, gender, age, ect will be reported and used to stratify the data accordingly. However these will be used to correlate possible etiologies of SCFEs while the main purpose will be to determine how the outcomes of the surgical procedure used at DCH compare to national averages amongst other reported outcomes.

Results

The demographics of the patients and comparisons between males and females are shown in Table 1. Of note there were 144 males and 78 females in the 222 total cases reviewed. Male patients were slightly older and a higher percent had BMIs ≥95th percentile. Female patients were significantly more likely to have endocrinopathy compared to males (Table 1). A total of 203 ISP procedures were used, 13 ISP with hip capsule decompression, and in 6 cases the modified Dunn technique was used. There were 12 instances of AVN (5.4%), 2 of chondrolysis (0.9%), 17 of FAI (7.7%), and 15 instances of hardware removal (6.8%) (Table 1).

BMI was available for 169 patients and was converted to percentiles based on age and gender. Table 2 shows the comparisons between patients with BMI <95th percentile vs. ≥95th percentile on clinical variables and complications. There were no differences between the groups for comorbidities, SCFE classification, surgical complications, or surgical fixation technique (Tables 2, 3).

Of the 12 cases of AVN, ISP was used in 7 of the hips (3.4% of ISP cases), 1 case involved ISP with hip capsule decompression (7.7% of ISP with hip capsule decompression), and 4 cases used the modified Dunn technique (66.7% of modified Dunn cases). It is of note that the cases ofAVN reported with the modified Dunn technique were performed by 1 surgeon. Table 3 shows the comparisons of patients with and without AVN for age, BMI, clinical variables, and other complications. AVN was significantly associated with the type of surgical fixation, the need for return to the operating room (OR), and surgical complications (Tables 3,4,5) .

In this study, patients with a history of endocrinopathy had a significantly higher rate of hardware removal compared to patients with no comorbidities (16.0% vs. 3.3%, P<0.05) (Table 5). There were no other significant risk factors associated with post operative complications.

Table 1. Descriptive statistics for all patients, and comparisons between males and females

Variable	All patients	Males	Females	P value
Age (yrs), mean (SD)	12.5 (1.9)	13.1 (1.9)	11.4 (1.5)	**<0.001**
Range	7-24	7-24	8-15	
	(n=222)	(n=144)	(n=78)	
BMI (kg/m^2), mean (SD)	29.0 (6.1)	30.3 (5.9)	27.0 (5.8)	**<0.001**
Range	16.4-44.5	16.4-44.5	17.2-43.0	
	(n=169)	(n=102)	(n=67)	

	n (%)	n (%)	n (%)	
BMI for age and gender				**0.002**
<95th percentile	46 (27.2)	19 (18.6)	27 (40.3)	
≥95th percentile	123 (72.8)	83 (81.4)	40 (59.7)	
Comorbidities				**0.024**
None	152 (68.5)	103 (71.5)	49 (62.8)	
Endocrinopathy	50 (22.5)	25 (17.4)	25 (32.1)	
Other[a]	20 (9.0)	16 (11.1)	4 (5.1)	
Classification				0.787
Acute	59 (26.6)	40 (27.8)	19 (24.4)	
Acute on chronic	21 (9.5)	15 (10.4)	6 (7.7)	
Chronic	138 (62.2)	86 (59.7)	52 (66.7)	
Preslip	4 (1.8)	3 (2.1)	1 (1.3)	
Surgical fixation				**0.028**
ISP	203 (91.4)	136 (94.4)	67 (85.9)	
ISP+hip capsule decompression	13 (5.9)	7 (4.9)	6 (7.7)	
Modified Dunn[b]	6 (2.7)	1 (0.7)	5 (6.4)	
Return to OR (n, % yes)	30 (13.5)	20 (13.9)	10 (12.8)	0.824
Surgical complication (n, % yes)	3 (1.4)	3 (2.1)	0 (0.0)	0.554
Complication				0.415
None	176 (79.3)	114 (79.2)	62 (79.5)	
AVN	12 (5.4)	9 (6.3)	3 (3.8)	
Chondrolysis	2 (0.9)	2 (1.4)	0 (0.0)	
FAI	17 (7.7)	8 (5.6)	9 (11.5)	
Hardware removal	15 (6.8)	11 (7.6)	4 (5.1)	
Any complication (n, % yes)	46 (20.7)	30 (20.8)	16 (20.5)	0.955

AVN (n, % yes)	12 (5.4)	9 (6.3)	3 (3.8)	0.547
Chondrolysis (n, % yes)	2 (0.9)	2 (1.4)	0 (0.0)	0.542
FAI (n, % yes)	17 (7.7)	8 (5.6)	9 (11.5)	0.110
Hardware removal (n, % yes)	15 (6.8)	11 (7.6)	4 (5.1)	0.477

[a]P<0.05 compared to endocrinopathy, [b]P<0.05 compared to ISP technique, Bonferroni multiple comparisons tests.

Table 2. Comparisons between patients with BMI <95th percentile vs. ≥95th percentile

Variable	BMI <95th percentile	BMI ≥95th percentile	P value
Age (yrs), mean (SD)	12.5 (1.9)	12.2 (1.7)	0.262
Range	7-16	8-18	
	(n=46)	(n=123)	
	n (%)	n (%)	
Comorbidities			0.844
None	26 (56.5)	75 (61.0)	
Endocrinopathy	14 (30.4)	35 (28.5)	
Other	6 (13.0)	13 (10.6)	
Classification			0.377
Acute	16 (34.8)	31 (25.2)	
Acute on chronic	5 (10.9)	10 (8.1)	
Chronic	25 (54.3)	78 (63.4)	
Preslip	0 (0.0)	4 (3.3)	
Surgical fixation			0.182
ISP	42 (91.3)	110 (89.4)	
ISP + hip capsule decompression	1 (2.2)	10 (8.1)	

Modified Dunn	3 (6.5)	3 (2.4)	
Return to OR (n, % yes)	6 (13.0)	22 (17.9)	0.451
Surgical complication (n, % yes)	2 (4.3)	1 (0.8)	0.180
Complication			0.494
None	33 (71.7)	99 (80.5)	
AVN	4 (8.7)	5 (4.1)	
Chondrolysis	0 (0.0)	0 (0.0)	
FAI	5 (10.9)	10 (8.1)	
Hardware removal	4 (8.7)	9 (7.3)	
Any complication (n, % yes)	13 (28.3)	24 (19.5)	0.221
AVN (n, % yes)	4 (8.7)	5 (4.1)	0.257
Chondrolysis (n, % yes)	0 (0.0)	0 (0.0)	na
FAI (n, % yes)	5 (10.9)	10 (8.1)	0.555
Hardware removal (n, % yes)	4 (8.7)	9 (7.3)	0.752

Table 3: Displays Surgical fixation with its associated Complications

Variable	Level	ISP # (%)	ISP + hip cap decomp # (%)	Modified Dunn # (%)	P value
Gender	Males	136 (67.0)	7 (53.8)	1 (16.7)**a**	**0.028**
	Females	67 (33.0)	6 (46.2)	5 (83.3)	f
BMI ≥95th percentile for age and gender	<95th percentile	42 (27.6)	1 (9.1)	3 (50.0)	0.182
	≥95th percentile	110 (72.4)	10 (90.9)	3 (50.0)	f
Comorbidities	None	137 (67.5)	9 (69.2)	6 (100.0)	0.755
	Endocrinopathy	47 (23.2)	3 (23.1)	0 (0.0)	f
	Other	19 (9.4)	1 (7.7)	0 (0.0)	
Classification	Acute	48 (23.6)	9 (69.2)**a**	2 (33.3)	**0.006**
	Acute on chronic	18 (8.9)	2 (15.4)	1 (16.7)	f
	Chronic	133 (65.5)	2 (15.4)	3 (50.0)	
	Preslip	4 (2.0)	0 (0.0)	0 (0.0)	
Return to OR	No	175 (86.2)	12 (92.3)	5 (83.3)	0.875
	Yes	28 (13.8)	1 (7.7)	1 (16.7)	f
Surgical complication	No	201 (99.0)	13 (100.0)	5 (83.3)	0.088
	Yes	2 (1.0)	0 (0.0)	1 (16.7)	f

Complication	None AVN Chondrolysis FAI Hardware removal	162 (79.8) 7 (3.4) 2 (1.0) 17 (8.4) 15 (7.7)	12 (92.3) 1 (7.7) 0 (0.0) 0 (0.0) 0 (0.0)	2 (33.3)**a,b** 4 (66.7) 0 (0.0) 0 (0.0) 0 (0.0)	**0.004** f
Any complication (of AVN, chondrolysis, FAI, hardware removal)	No Yes	162 (79.8) 41 (20.2)	12 (92.3) 1 (7.7)	2 (33.3)**a,b** 4 (66.7)	**0.018** f
AVN	No Yes	196 (96.6) 7 (3.4)	12 (92.3) 1 (7.7)	2 (33.3)**a** 4 (66.7)	**<0.001** f
Chondrolysis	No Yes	201 (99.0) 2 (1.0)	13 (100.0) 0 (0.0)	6 (100.0) 0 (0.0)	1.000 f
FAI	No Yes	186 (91.6) 17 (8.4)	13 (100.0) 0 (0.0)	6 (100.0) 0 (0.0)	0.757 f
Hardware removal	No Yes	188 (92.6) 15 (7.4)	13 (100.0) 0 (0.0)	6 (100.0) 0 (0.0)	0.743 f

Table 4. Comparisons between patients with vs. without AVN

Variable	No AVN	AVN	P value
Age (yrs), mean (SD)	12.5 (1.9)	12.9 (1.6)	0.439
Range	7-24	10-15	
	(n=222)	(n=12)	
BMI (kg/m^2), mean (SD)	28.9 (5.9)	29.7 (8.7)	0.789
Range	16.4-44.5	18.0-40.6	
	(n=160)	(n=9)	
	n (%)	n (%)	
Comorbidities			0.792
None	143 (68.1)	9 (75.0)	
Endocrinopathy	47 (22.4)	3 (25.0)	
Other	20 (9.5)	0 (0.0)	

Classification			0.502
Acute	55 (26.2)	4 (33.3)	
Acute on chronic	19 (9.0)	2 (16.7)	
Chronic	132 (62.9)	6 (50.0)	
Preslip	4 (1.9)	0 (0.0)	
Surgical fixation			**<0.001**
ISP	196 (93.3)	7 (58.3)	
ISP + hip capsule decompression	12 (5.7)	1 (8.3)	
Modified Dunn[a]	2 (1.0)	4 (33.3)	
Return to OR (n, % yes)	24 (11.4)	6 (50.0)	**<0.001**
Surgical complication (n, % yes)	1 (0.5)	2 (16.7)	**<0.001**

[a]P<0.05 compared to ISP technique, Bonferroni multiple comparisons test.

Table 4: Complication rates associated with each collected variable

Variable	Level	None n (%)	AVN n (%)	Chondro-lysis n (%)	FAI n (%)	Hardware removal n (%)	P value
Gender	Males	114 (64.8)	9 (75.0)	2 (100.0)	8 (47.1)	11 (73.3)	0.415
	Females	62 (35.2)	3 (25.0)	0 (0.0)	9 (52.9)	4 (26.7)	f
Comorbidities	None	123 (69.9)	9 (75.0)	2 (100.0)	13 (76.5)	5 (33.3)	0.147
	Endocrinopathy	36 (20.5)	3 (25.0)	0 (0.0)	3 (17.6)	8 (53.3)	f
	Other	17 (9.7)	0 (0.0)	0 (0.0)	1 (5.9)	2 (13.3)	
Classification	Acute	48 (27.3)	4 (33.3)	0 (0.0)	2 (11.8)	5 (33.3)	0.796
	Acute on chronic	15 (8.5)	2 (16.7)	0 (0.0)	3 (17.6)	1 (6.7)	f
	Chronic	109 (61.9)	6 (50.0)	2 (100.0)	12 (70.6)	9 (60.0)	
	Preslip	4 (2.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Return to OR	No	175 (99.4)	6 (50.0)**a**	2 (100.0)	9 (52.9)**a**	0 (0.0)**a,b,c,d**	**<0.001**
	Yes	1 (0.6)	6 (50.0)	0 (0.0)	8 (47.1)	15 (100.0)	f

Surgical complication	No	175 (99.4)	10 (83.3)**a**	2 (100.0)	17 (100.0)	15 (100.0)	**0.024**
	Yes	1 (0.6)	2 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)	f

a: P<0.05 vs. None group; **b**: P<0.05 vs. AVN group; **c**: P<0.05 vs. Chondrolysis group; **d**: P<0.05 vs. FAI group, Bonferroni multiple comparisons tests

Table 5: History of endocrinopathy compared to post-operative complications

Variable	Level	None # (%)	Endocrin-opathy # (%)	Other # (%)	P value
Gender	Males	103 (67.8)	25 (50.0)	16 (80.0)**b**	**0.024**
	Females	49 (32.2)	25 (50.0)	4 (20.0)	c
Classification	Acute	40 (26.3)	10 (20.0)**a**	9 (45.0)**a**	**0.014**
	Acute on chronic	16 (10.5)	3 (6.0)	2 (10.0)	f
	Chronic	96 (63.2)	34 (68.0)	8 (40.0)	
	Preslip	0 (0.0)	3 (6.0)	1 (5.0)	
Return to OR	No	136 (89.5)	38 (76.0)	18 (90.0)	0.061
	Yes	16 (10.5)	12 (24.0)	2 (10.0)	f
Surgical complication	No	149 (98.0)	50 (100.0)	20 (100.0)	1.000
	Yes	3 (2.0)	0 (0.0)	0 (0.0)	f
Complication	None	123 (80.9)	36 (72.0)	17 (85.0)	0.147
	AVN	9 (5.9)	3 (6.0)	0 (0.0)	f
	Chondrolysis	2 (1.3)	0 (0.0)	0 (0.0)	
	FAI	13 (8.6)	3 (6.0)	1 (5.0)	
	Hardware removal	5 (3.3)	8 (16.0)	2 (10.0)	
Any complication (of AVN, chondrolysis, FAI, hardware removal)	No	123 (80.9)	36 (72.0)	17 (85.0)	0.331
	Yes	29 (19.1)	14 (28.0)	3 (15.0)	f

AVN	No	143 (94.1)	47 (94.0)	20 (100.0)	0.792
	Yes	9 (5.9)	3 (6.0)	0 (0.0)	f
Chondrolysis	No	150 (98.7)	50 (100.0)	20 (100.0)	1.000
	Yes	2 (1.3)	0 (0.0)	0 (0.0)	f
FAI	No	139 (91.4)	47 (94.0)	19 (95.0)	0.919
	Yes	13 (8.6)	3 (6.0)	1 (5.0)	f
Hardware removal	No	147 (96.7)	42 (84.0)**a**	18 (90.0)	**0.005**
	Yes	5 (3.3)	8 (16.0)	2 (10.0)	f

Bonferroni multiple comparisons tests (paired comparisons when overall chi-square test is significant):

a: P<0.05 vs. None group; **b**: P<0.05 vs. Endocrinopathy group

Discussion

This study demonstrated a total AVN rate of 5.4%. This falls on the lower end compared to similar studies reporting AVN rates after treatment.[16] However, Reported AVN rates for SCFE surgical treatments differ among studies. In this study, there was a statistically significant difference in AVN rates based on the surgical technique used. ISP without hip capsule decompression demonstrated the lowest rate of 3.4% and ISP with hip capsule decompression at 7.7%. The ISP technique had a statistically significant lower rate of AVN when compared with the modified Dunn technique which had an AVN rate of 66.7% (4 out of 6 cases). In comparable studies, overall AVN rates for pinning procedures range from 1.4- 28%.[6,10,11] Similarly in comparable studies overall AVN rates for the modified Dunn procedure ranged from 3-43%.[17–24] Another study comparing the preliminary results of ISP versus the modified Dunn procedure demonstrated that there were similar AVN rates in both groups.[6,25] In our study, the modified

Dunn group showed the highest rate of AVN. One meta-analysis reports that variability in AVN rates shown in some studies may be attributed to the fact that they were performed at much higher volume centers; similar studies at lower volume centers displayed higher AVN rates..[2]

In this study, a history of endocrinopathy showed a higher rate of hardware removal when compared to patients with no history of endocrinopathy. In previously reported studies a history of endocrinopathy may be associated with worse post-operative complications in SCFE surgery. This was attributed to low serum level of vitamin D, which is a key regulator in bone homeostasis.[4] This may correlate to the complication of hardware removal seen in our study; however, vitamin D levels were not obtained during this study. Aside from this variable, there were not significant risk factors for FAI, hardware removal, and chondrolysis.

As previously mentioned, SCFE injuries are also classified by slip stability. In previous literature has shown that unstable SCFEs have higher rates of AVN after surgical treatment than stable SCFEs, ranging 23-60%[26,27]. This provides insight as to whether the development of AVN may be attributed to the slip stability vs. hip procedure used. Although we did not include slip stability in the analysis, it is possible that AVN may be correlated with the slip stability of the patient's SCFE. However, even if the onset of AVN is correlated with slip stability, it is unlikely to be causative, as it is more likely that the slip stability would influence the surgeon's preferred method of treatment, which would in turn affect the incidence of AVN.

Conclusion

There are several limitations to this study. The study was performed at one hospital using one group of pediatric orthopaedic surgeons. The study took place at a hospital with moderate patient volume. Studies with higher or lower volume of orthopedic cases may observe different results,

and our formation may not be generalizable to those hospitals. Finally, since the predominant procedure used at DCH was ISP it is more difficult to generalize the findings for other procedures.

This study demonstrated that the total AVN rates after SCFE procedures at DCH are comparable to previously reported studies where the procedure primarily used was in situ pinning. This study found statistical significance while observing the type of procedure used, patients who received ISP had statistically significantly lower rates of AVN than patients treated with the modified Dunn technique. Endocrinopathy was associated with a higher rate of hardware removal which was considered a post-operative complication. No other significant risk factors were seen. The rates for AVN after in situ pinning were at the lower end of the previously reported while the rates of the modified Dunn were at the higher end of previously reported ranges. It may be useful to utilize a higher power study using a multicenter approach to look at AVN rates while using the modified Dunn technique.

Reference

1. Azegami S, Kosuge D, Ramachandran M. Surgical treatment of femoroacetabular impingement in patients with slipped capital femoral epiphysis: A review of current surgical techniques. *Bone Joint J*. 2013;95-B(4):445-451. doi:10.1302/0301-620X.95B4.30245
2. Novais EN, Millis MB. Slipped capital femoral epiphysis: prevalence, pathogenesis, and natural history. *Clin Orthop Relat Res*. 2012;470(12):3432-3438. doi:10.1007/s11999-012-2452-y
3. Klein C, Haraux E, Leroux J, Gouron R. [Slipped capital femoral epiphysis]. *Arch Pediatr*. 2017;24(3):301-305. doi:10.1016/j.arcped.2016.12.011
4. Ucpunar H, Camurcu IY, Duman S, Ucpunar E, Sofu H, Bayhan AI. Obesity-related metabolic and endocrine disorders diagnosed during postoperative follow-up of slipped capital femoral epiphysis. *Acta Orthop*. 2018;89(3):314-319. doi:10.1080/17453674.2018.1445167
5. Perry DC, Metcalfe D, Lane S, Turner S. Childhood Obesity and Slipped Capital Femoral Epiphysis. *Pediatrics*. 2018;142(5). doi:10.1542/peds.2018-1067
6. Novais EN, Maranho DA, Heare T, Sink E, Carry PM, O'Donnel C. The modified Dunn procedure provides superior short-term outcomes in the treatment of the unstable slipped capital femoral epiphysis as compared to the inadvertent closed reduction and percutaneous pinning: a comparative clinical study. *Int Orthop*. 2019;43(3):669-675. doi:10.1007/s00264-018-3993-9
7. Davis RL 2nd, Samora WP 3rd, Persinger F, Klingele KE. Treatment of Unstable Versus Stable Slipped Capital Femoral Epiphysis Using the Modified Dunn Procedure. *J Pediatr Orthop*. 2019;39(8):411-415. doi:10.1097/BPO.0000000000000975
8. Otani T, Kawaguchi Y, Marumo K. Diagnosis and treatment of slipped capital femoral epiphysis: Recent trends to note. *J Orthop Sci*. 2018;23(2):220-228. doi:10.1016/j.jos.2017.12.009
9. Aprato A, Conti A, Bertolo F, Masse A. Slipped capital femoral epiphysis: current management strategies. *Orthop Res Rev*. 2019;11:47-54. doi:10.2147/ORR.S166735
10. Herngren B, Stenmarker M, Enskar K, Hagglund G. Outcomes after slipped capital femoral epiphysis: a population-based study with three-year follow-up. *J Child Orthop*. 2018;12(5):434-443. doi:10.1302/1863-2548.12.180067
11. Naseem H, Chatterji S, Tsang K, Hakimi M, Chytas A, Alshryda S. Treatment of stable slipped capital femoral epiphysis: systematic review and exploratory patient level analysis. *J Orthop Traumatol*. 2017;18(4):379-394. doi:10.1007/s10195-017-0469-4
12. Wylie JD, Novais EN. Evolving Understanding of and Treatment Approaches to Slipped Capital Femoral Epiphysis. *Curr Rev Musculoskelet Med*. 2019;12(2):213-219. doi:10.1007/s12178-019-09547-5
13. Fraitzl CR, Käfer W, Nelitz M, Reichel H. Radiological evidence of femoroacetabular impingement in mild slipped capital femoral epiphysis: a mean follow-up of 14.4 years after pinning in situ. *J Bone Joint Surg Br*. 2007;89(12):1592-1596. doi:10.1302/0301-620X.89B12.19637
14. Zilkens C, Bittersohl B, Jäger M, et al. Significance of clinical and radiographic findings in young adults after slipped capital femoral epiphysis. *Int Orthop*. 2011;35(9):1295-1301. doi:10.1007/s00264-010-1106-5
15. Rostoucher P, Bensahel H, Pennecot GF, Kaewpornsawan K, Mazda K. Slipped capital

femoral epiphysis: evaluation of different modes of treatment. *J Pediatr Orthop B*. 1996;5(2):96-101. doi:10.1097/01202412-199605020-00008

16. Fallath S, Letts M. Slipped capital femoral epiphysis: an analysis of treatment outcome according to physeal stability. *Can J Surg*. 2004;47(4):284-289.
17. Ziebarth K, Zilkens C, Spencer S, Leunig M, Ganz R, Kim Y-J. Capital realignment for moderate and severe SCFE using a modified Dunn procedure. *Clin Orthop Relat Res*. 2009;467(3):704-716. doi:10.1007/s11999-008-0687-4
18. Slongo T, Kakaty D, Krause F, Ziebarth K. Treatment of slipped capital femoral epiphysis with a modified Dunn procedure. *J Bone Joint Surg Am*. 2010;92(18):2898-2908. doi:10.2106/JBJS.I.01385
19. Huber H, Dora C, Ramseier LE, Buck F, Dierauer S. Adolescent slipped capital femoral epiphysis treated by a modified Dunn osteotomy with surgical hip dislocation. *J Bone Joint Surg Br*. 2011;93(6):833-838. doi:10.1302/0301-620X.93B6.25849
20. Madan SS, Cooper AP, Davies AG, Fernandes JA. The treatment of severe slipped capital femoral epiphysis via the Ganz surgical dislocation and anatomical reduction: a prospective study. *Bone Joint J*. 2013;95-B(3):424-429. doi:10.1302/0301-620X.95B3.30113
21. Upasani V V, Matheney TH, Spencer SA, Kim Y-J, Millis MB, Kasser JR. Complications after modified Dunn osteotomy for the treatment of adolescent slipped capital femoral epiphysis. *J Pediatr Orthop*. 2014;34(7):661-667. doi:10.1097/BPO.0000000000000161
22. Souder CD, Bomar JD, Wenger DR. The role of capital realignment versus in situ stabilization for the treatment of slipped capital femoral epiphysis. *J Pediatr Orthop*. 2014;34(8):791-798. doi:10.1097/BPO.0000000000000193
23. Persinger F, Davis RL 2nd, Samora WP, Klingele KE. Treatment of Unstable Slipped Capital Epiphysis Via the Modified Dunn Procedure. *J Pediatr Orthop*. 2018;38(1):3-8. doi:10.1097/BPO.0000000000000737
24. Elmarghany M, Abd El-Ghaffar TM, Seddik M, et al. Surgical hip dislocation in treatment of slipped capital femoral epiphysis. *SICOT-J*. 2017;3:10. doi:10.1051/sicotj/2016047
25. Trisolino G, Stilli S, Gallone G, Santos Leite P, Pignatti G. Comparison between modified Dunn procedure and in situ fixation for severe stable slipped capital femoral epiphysis. *Acta Orthop*. 2018;89(2):211-216. doi:10.1080/17453674.2018.1439238
26. Zaltz I, Baca G, Clohisy JC. Unstable SCFE: review of treatment modalities and prevalence of osteonecrosis. *Clin Orthop Relat Res*. 2013;471(7):2192-2198. doi:10.1007/s11999-012-2765-x
27. Kaushal N, Chen C, Agarwal KN, Schrader T, Kelly D, Dodwell ER. Capsulotomy in Unstable Slipped Capital Femoral Epiphysis and the Odds of AVN: A Meta-analysis of Retrospective Studies. *J Pediatr Orthop*. 2019;39(6):e406-e411. doi:10.1097/BPO.0000000000001359